Quantitative Characterization of Mesoscale Objects

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We have used several NDC tools and procedures to quantitatively characterize the performance of mesoscale (mm-size extent with μm-size features) systems, to determine which systems may have the best potential to meet our mesoscale imaging needs.

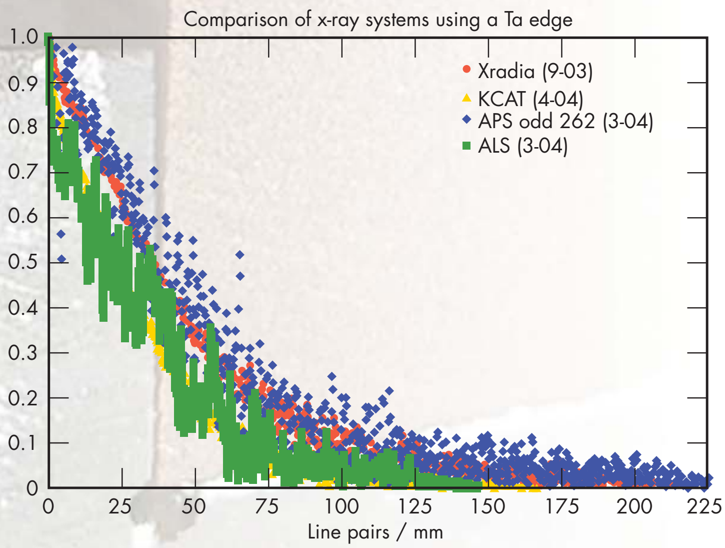

Figure 1. MTFs determined from digital radiographs of a 0.51-mm-thick Ta edge for four microtomography x-ray systems, as labeled. The two systems with camera lens coupled to a CCD detector (KCAT and ALS) have similar MTFs, while the two systems with microscope lens coupled to a CCD detector systems (Xradia and APS) have similar and better MTFs. The microfocus-source systems (KCAT and Xradia) have a less noisy MTF than the synchrotron-based systems.

Project Goals

Our project goal was to quantify the performance of mesoscale imaging systems. We chose four x-ray systems: two microfocus systems, KCAT (LLNL) and Xradia μXCT (Xradia, Inc., Concord, California); and two synchrotron-based systems, Beamline 1-ID at the Advanced Photon Source (APS) and the Tomography Beamline at the Advanced Light Source (ALS).

Relevance to LLNL Mission

This project directly supports long-term plans to apply and understand mesoscale characterization techniques, and to build a facility to fabricate and characterize mesoscale target assemblies for studying high-energy-density physics (HEDP). Understanding and benchmarking the capabilities of these systems will enable the science and technology of phase-contrast modeling and object recovery. LLNL programs that would

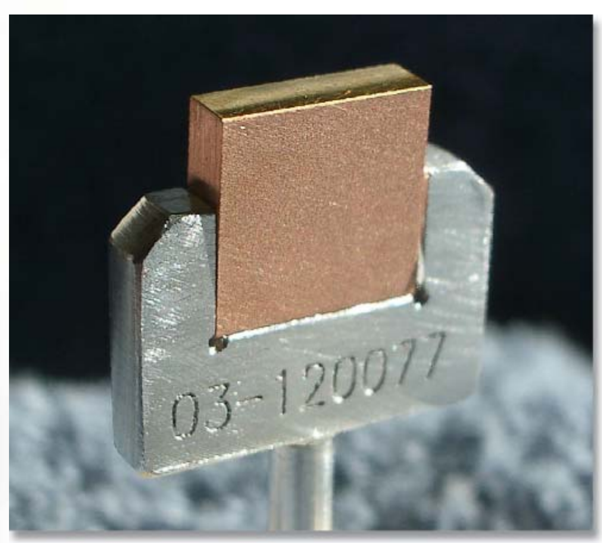

Figure 2. Photograph of one large radius of curvature edge made of Cu coated with Au and used to measure 2-D MTF.

benefit from this project include HEDP and inertial confinement fusion experiments for NIF. This project is consistent with LLNL's plans to study the suitability of applying known engineering approaches to solve problems of interest.

FY2004 Accomplishments and Results

We have benchmarked the four x-ray mesoscale imaging systems described above, quantifying the 2-D DR performance by measuring the 2-D Modulation Transfer Function (MTF) and signal-to-noise ratio (SNR) using edge artifacts. First, a thin tantalum foil was used to measure MTF and SNR. MTF results for each of the four systems are shown in Fig. 1.

Due to the excessive raggedness of the edge on the tantalum foil, we fabricated eight serialized Au-plated Cu edges, shown in Fig. 2. It has previously been shown that for HEDP imaging, x rays at 10 to 80 keV are of interest. The new Au-plated Cu edges provide a transmission of 1% for 60-keV photons passing through the edge 1 μm from the surface. Additional MTF and SNR measurements were made using the new edges and compared to the results for the tantalum foil.

We then imaged more complex objects such as the mesoscale spherical reference standards built in FY2003 (Fig. 3). DR and CT data was also acquired for the planar reference standard. The 2- and 3-D data from the mesoscale reference standards was used to create meshes for input to finite element analyses.

Next, we characterized the 3-D CT performance of the systems by measuring the 3-D MTF and SNR of each system using tubes of different materials, shown in Fig. 4. The tubes selected were chosen to represent a broad range of typical target materials and densities. The MTF measurements from CT images were made for the inner and outer edges of each tube. Finally, dimensional measurements, such as wall thickness of the tubes, were determined using CT data.

FY2005 Proposed Work

Future work will include additional techniques to extract quantitative measurements of system performance. A more detailed system error analysis would also be useful as another benchmark of system performance. Finally, the 3-D data acquired with the x-ray systems should be analyzed to extract quantitative dimensional information about complex mesoscale objects. Information that can be extracted includes void content, bond/joint integrity, sphericity and concentricity of components, and overall as-built quality.

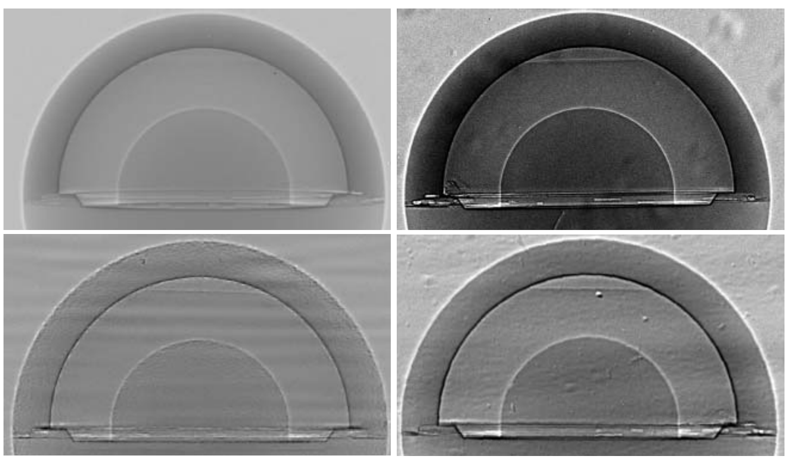

Figure 3. Transmission images of spherical mesoscale reference standard acquired with four x-ray systems. Top left: KCAT, top right: Xradia, bottom left: ALS, bottom right: Beamline 1-ID APS.

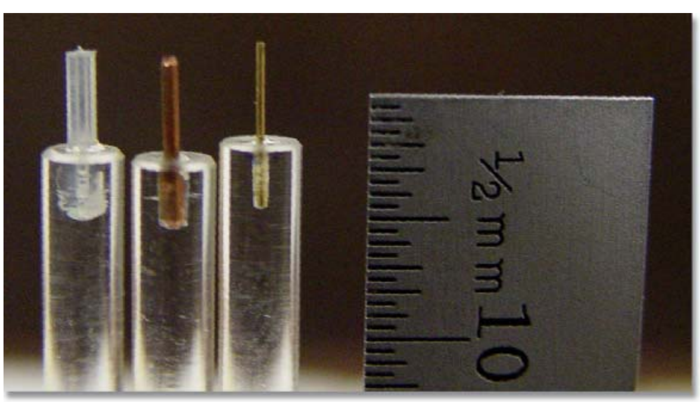

Figure 4. Photograph of tubes used to measure 3-D MTF. From left: low-density polyethylene (LDPE), Cu and Au.